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ON THE DISTRIBUTION OF LOWER TRIASSIC FAUNAS¹

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No formation has added more in recent years to our knowledge of ancient faunal geography than the Lower Triassic. In this epoch we now know three distinct and widely distributed interregional faunal zones, which are truly bench-marks in correlation. These are in sequence upward: (1) the *Meekoceras* zone; (2) the *Tirolites* zone; (3) the *Columbites* zone. They do not have the same distribution, nor are the relationships of the various regions constant for the successive epochs, showing that there was considerable change in physical geography during the Lower Triassic. Critical studies of these faunas from Siberia, India, Madagascar, the Indian Archipelago, and western America have made it possible for us to understand the ancient faunal geography in a way that was impossible a few years ago.

FAUNAS OF THE MEEKOCERAS ZONE

The Meekoceras fauna of Madagascar.—During the past year Dr. H. Douvillé² has announced the discovery of the *Meekoceras* fauna on Madagascar; with *Meekoceras* cf. *gracilitatis*, *Flemingites*, *Cordillerites*, and *Lecanites*, all closely allied to species in the American fauna. This argues for a connection during this epoch between the Great Basin Sea and the Indian Ocean. Madagascar and the Great Basin of western America are almost exactly opposite each other on the globe, and the distance would be about twelve thousand miles by a great circle. From the Great Basin to Madagascar around the old shore line of the North Pacific, and then down the Asiatic coast and around the old shore line of the ancient Australasian land-mass, would be about twenty-one thousand miles. But if

¹ Published by permission of the Director of the U.S. Geological Survey.

² *Compt. rendus. Acad. Sci.*, 1910, p. 210; and *Bull. Soc. géol. France*, 4^e sér., Tome X, pp. 125.

there was an arm of the sea connecting the Indian Tethys with the southern Indian Ocean the distance would not be more than fourteen thousand miles. This geosyncline, or arm of the sea, did exist in Jurassic time, and it is probable that the occurrence of the Pacific-Asiatic fauna of the *Meekoceras* zone in Madagascar marks the birth of the Indian Ocean.

The Meekoceras fauna of the Indian Archipelago.—Dr. J. Wanner¹ has recently described the *Meekoceras* fauna of the Island of Timor in the Indian Archipelago, listing from there; *Meekoceras*, *Flemingites*, and *Pseudosagoceras multilobatum*, with species all closely related to forms already known in India and in the Great Basin Sea, showing the existence of the Tethys during this epoch.

The Meekoceras fauna in India and Siberia.—The *Meekoceras* fauna of India has long been known, but a recent work by Diener and von Krafft² has added greatly to our knowledge, and has made possible exact comparisons and correlations of faunas. In this monograph Diener and von Krafft bring out very clearly the intimate relations existing between the Indian, the Siberian, and the western American faunas of this zone.

The Arctic Meekoceras faunas.—The *Posidonomya* beds of Spitzbergen have long passed as Middle Triassic, but they contain several species almost identical with forms in the *Meekoceras* beds of Idaho. They were described as "*Ceratites*" but there can be no doubt that "*Ceratites*" *costatus* belongs to *Flemingites*, and that "*Ceratites*" *polaris* and *C. whitei* belong to *Meekoceras*, very closely allied to *M. mushbachanum*, all typical of the Lower Triassic. This fauna must then be placed in the Brahmantic stage of the Lower Triassic. The only argument against this conclusion is the supposed occurrence in the Spitzbergen beds of a *Monophyllites* of Middle Triassic character. But this species is almost identical with *M. sphaerophyllus*, a group typical of the higher Muschelkalk beds of Bosnia, India, and Nevada, and the specimen probably came out of the *Daonella* beds of Spitzbergen, which do contain an upper Muschelkalk fauna. Such a

¹ *Centralblatt für Min. Geol. und Pal.* 1909, pp. 137-47; 1910, p. 736; *Neues Jahrb. für Min.* etc., 1911, Beilage Bd. No. XXXII, pp. 177-96.

² "Lower Triassic Cephalopoda from Spiti, Malla Johar, and Byans," *Pal. Indica.*, Ser. XV, Vol. VI, No. 1, 1909.

confusion of species might easily happen, under the conditions of collecting in that region.

The *Meekoceras* fauna of southwestern Siberia, Thibet, and India is too well known to need further discussion here. It contains this same assemblage of genera already mentioned, mostly near allies of the genus *Meekoceras*. This fauna has been described in numerous monographs by Waagen, Diener, Noetling, and Griesbach, and has become the standard of comparison for the rest of the world.

The Meekoceras fauna in western America.—In southeastern Idaho and in the Inyo Mountains of California the *Meekoceras* fauna has been described in the works of C. A. White, Alpheus Hyatt, and the writer, with a wealth of genera similar to those of Asia, and some few identical species. The most characteristic genera are: *Meekoceras*, *Aspidites*, *Flemingites*, *Hedenstroemia*, *Pseudosageceras*, *Cordillerites*, *Lanceolites*, *Xenodiscus*, *Nannites*, *Inyoites*, *Owenites*, and *Lecanites*.

The writer has recently found this same fauna near the ranch of Henry Phelan, in White Pine County in eastern Nevada, about seventy miles south of Wells station on the Central Pacific Railroad. This locality is about half-way between the localities in California and Idaho, and distant over three hundred miles from each. The following is a preliminary list of the species identified: *Meekoceras gracilitatis*, *M. cf. mushbachanum*, *M. cf. radiosum* Waagen, *Prop-tychites cf. Walcottii*, *Lanceolites* sp. nov., *Pseudosageceras intermontanum*, *Aspenites acutus*, *Inyoites oweni*, *Owenites cf. koeneni*, *Nannites dieneri*, *Paranannites cf. aspenensis*, *Ophiceras* sp. nov., *Xenodiscus cf. whiteanus* Waagen, *X. cf. nivalis* Diener, *Pseudomonotis cf. idahoensis*.

By a comparison with lists from Idaho and from California it will be seen that the affinities with the latter are closer than with Idaho, although the two provinces were intimately related, and the new locality in Nevada gives a perfect connecting link, as it should, from its geographic position.

The *Meekoceras* fauna is one of the most distinctive and widely defined interregional correlation zones in the world, being known from Spitzbergen on the north, through the equatorial region of

Timor, to Madagascar on the south; from India on the west, through the Tethys to southeastern Siberia, to the Great Basin Sea of western America. It is not known in the Mediterranean region, nor in South America, Africa, nor Australia. Its genera and species are closely related in all the regions mentioned, so that an intimate connection between those regions is certain. It would seem probable that at this time there was a barrier between the Poseidon Ocean and the Pacific, and between the Mediterranean and the Oriental Tethys. It is certain that there was a connection between the North Pacific and the Arctic Ocean, and that the Great Basin Sea opened into the North Pacific. It is equally certain that the North Pacific was connected with the Oriental Tethys through the Archipelago north of Australia, this narrow sea extending westward to India, and southward in a great geosyncline to Madagascar.

The distribution of the *Meekoceras* fauna rivals, and even surpasses, that of the *Arietites* fauna of the Lias. Truly, this speaks for remarkably uniform conditions in the sea of that time, but whether warm, temperate, or cold we cannot say, for we know nothing of the corals in the sea, nor of the land plants, which might give us some indication of the temperature.

THE TIROLITES FAUNA

The *Tirolites* fauna has long been known in the Mediterranean region, where it was formerly supposed to be the only one. It is especially characterized by the abundance of the genus *Tirolites*, which until recently was supposed to be confined to this region.

In recent years the writer¹ has described the occurrence of the *Tirolites* fauna in southeastern Idaho, with *Tirolites* cf. *cassianus* Quenstedt, *T.* cf. *haueri* Mojsisovics, *T.* cf. *smiriagini* Mojsisovics, *Dalmatites* cf. *morlaccus* Kittl, *Dinarites* sp. nov., etc.

This fauna is of decidedly Mediterranean character, and unlike anything known elsewhere, though Diener and von Krafft have described a single species of *Tirolites* from the Lower Triassic of India. The close relationship of the *Tirolites* fauna of Idaho with

¹ Festschrift—Adolf von Koenen (1907), *The Stratigraphy of the Western American Trias*, 398–99.

that of the Alpine Province of the Mediterranean region shows an intimate connection, not through the Oriental Tethys, but rather through the Poseidon Ocean. At that time there was no barrier between the Caribbean Sea and the Pacific, but the portal between the Pacific and the Oriental Tethys was probably closed, as was also the portal between the Oriental Tethys and the Mediterranean.

THE COLUMBITES FAUNA

The *Columbites* fauna of Idaho was described by Alpheus Hyatt and the writer,¹ from a single locality near the town of Paris. It is characterized by the abundance of the genus *Columbites*, a member of the family *Tropitidae*, *Ophiceras*, *Xenodiscus*, *Pseudosageceras*, with a few species that have survived from the older *Meekoceras* fauna. There was also found in it a single species of *Tirolites* near *T. seminudus* Mojsisovics, a survivor from the underlying *Tirolites* zone. At the time when this fauna was described it was supposed to be unique, nothing like it being known anywhere, though the writer recognized its kinship to the Olenek fauna of northern Siberia.

The section at Paris Canyon is very instructive, for there is exposed the entire sequence of the Lower Triassic. At the base are the *Meekoceras* beds—yellowish-gray limestones—about twenty-five feet thick, with *Meekoceras gracilitatis*, *Flemingites cirratus*, *Ussuria waageni*, *Nannites dieneri*, *Pseudosageceras intermontanum*, *Lanceolites compactus*, and many other forms characteristic of this horizon.

About two hundred and fifty feet higher up in the section are the *Tirolites* beds—gray calcareous shales—with the forms listed under the *Tirolites* fauna. About twenty-five feet higher is a thin bed of brownish bituminous limestone, in which the *Columbites* fauna was found, containing *Columbites parisianus*, several other species of the same genus, *Xenaspis*, *Xenodiscus*, *Celtites*, *Pseudoharpoceras*, *Ophiceras*, *Meekoceras*, and *Pseudosageceras intermontanum*, besides a *Tirolites* near *T. seminudus* Mojsisovics. The *Meekoceras* and *Pseudosageceras* are survivors from the *Meekoceras* beds, while the *Tirolites* has lived over from the preceding *Tirolites* fauna.

This *Columbites* fauna in Idaho is very important in settling the

¹ Professional Papers U.S. Geol. Survey No. ⁴⁰50, 1905.

age of certain disputed beds thousands of miles away, occurring, as it does, associated with survivors from the underlying beds in the same section, and above both the *Tirolites* and the *Meekoceras* faunas in the same canyon. In the first place, this proves the Lower Triassic age of the *Meekoceras* beds, if further proof were needed, since several abundant and characteristic species range through the entire section, and since the *Tirolites* beds, only a few feet below, contain a fauna virtually identical with that of the classic Campil beds, the type of the marine Lower Triassic of the Mediterranean region. But the *Columbites* beds belong to a horizon higher than any yet found to be fossiliferous in the original Mediterranean section, that is, to the barren upper Campil beds, as will be shown later in the discussion of the Albanian occurrence of this formation.

The Olenek beds of northern Siberia have long passed as the equivalents of the upper part of the Lower Triassic, but without any definite proof. Now since the faunas of the Olenek beds of Siberia and of the *Columbites* beds of Idaho are so closely related, and the stratigraphic position of the latter is positively known, the long-desired proof is brought. The Olenek beds are Lower Triassic, but younger than the *Tirolites* beds of the Mediterranean region.

Further proof of the validity of these conclusions has recently been published by Dr. G. von Arthaber,¹ from Albania on the Balkan Peninsula. Dr. von Arthaber describes from that region an assemblage of genera very like that of the *Columbites* fauna of Idaho, with some species that he considers identical; they include: *Columbites*, *Meekoceras*, *Celtites*, *Hedenstroemia*, *Sageceras*, *Pseudosageceras*, *Nannites*, *Lecanites*, *Pronorites*, *Tirolites*, *Parapopanoceras*, etc. According to Dr. von Arthaber, *Pseudosageceras multilobatum* Noetling is the same as *P. intermontanum* H. and S., and *Nannites heberti* is identical with *N. dieneri* H. and S., and those two species are also known in the *Hedenstroemia* beds of India. I do not agree with him as to the Albanian species of *Pseudosageceras*, which seems to me to be identical with *P. intermonta-*

¹ "Ueber die Entdeckung von Untertrias in Albanien und ihre faunistische Bewertung," *Mittheil. Geol. Gesell. Wien*, I (1908), 245-89; and "Ueber neue Funde in der Untertrias von Albanien," *ibid.*, II, 1909, 227-34.

num, but not with *P. multilobatum*. In fact, it does not seem to me that any species of the Albanian fauna is identical with any from India, but that the relationship is nearer to the boreal Olenek fauna and to the American *Columbites* fauna. This seems to the writer to be a boreal fauna that came down to the Mediterranean on one side, and to Idaho on the other. We know such a boreal invasion, in the Upper Triassic, when the *Pseudomonotis subcircularis* fauna came down to the Crimea on the one side, and to California on the other. It is probable that in Triassic time there was a depression connecting the Mediterranean with the Arctic Sea, and that periodic migrations came southward through this. In Idaho it was undoubtedly such an incursion. It is possible, however, that the appearance of the *Columbites* fauna in Mediterranean waters may be the beginning of an Indian immigration, which culminated in the lower part of the Middle Triassic as recorded by the Indian fauna of the Gulf of Ismid in Asia Minor.

To sum up, it seems probable that during the Brahmannic epoch of the Lower Triassic the Indian Region was the distributing point for the *Meekoceras* fauna, and that the swarming inhabitants of that sea migrated outward in all directions where marine connections permitted, reaching Spitzbergen on the north, Madagascar on the south, and the Great Basin Sea on the east; but that there was no connection between the Oriental and the Mediterranean divisions of the Tethys, nor between the Mediterranean-Poseidon waters and the Pacific.

During the *Tirolites* epoch a connection was opened between the Mediterranean-Poseidon Ocean and the Great Basin, but the latter body of water was not connected closely with the Arctic Ocean.

During the *Columbites* epoch the center of distribution of the known faunas seems to have been the Boreal Sea, from which migrations came southward to the border of the Mediterranean region, probably through Asia, and down to the Great Basin through the northern passage. There was probably no direct connection between the Poseidon-Mediterranean Ocean and the Pacific, nor any very close union between the eastern and the western divisions of the Tethys.

These periodic shiftings of ancient geographic relations do not show shiftings of the ancient seas, but rather prove the periodic opening and closing of the gateways connecting them. These gateways, or portals, are areas of depression on or between continental masses, and lie in regions of permanent instability of the earth's crust, where mountain-building, and the accompanying volcanic and earthquake disturbances have been prevalent. Some of these ancient portals are temporarily open now, on account of recent subsidence, as, for instance, the Bering Strait; another has been recently opened, by the activity of man—the Suez Canal. And the Panama Canal will restore a connection between the Atlantic and Pacific, which is temporarily closed on account of recent elevation in that region. One of these portals, that connecting the Oriental Tethys with the southern waters, has expanded into the Indian Ocean. Others of the ancient portals are now concealed in continental masses, and their very existence would not be suspected without studies in interregional relationships of faunas.